Study on response of RCC elevated circular water tank under seismic loading

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Abstract: **Seismic excitation causes severe structural damage. Elevated water tanks are frequently used structures for various purposes like water supply, irrigation, etc. Thus, seismic behavior of these tanks needs to be studied. Horizontal vibration due to seismic forces causes sloshing of water in tanks which can be threat to the structure. This paper aims to study the sloshing effect on elevated circular water tank for different water columns and heights of tank. Software package STAAD.Pro is used for analysis. Three different tank models are analyzed and parametric study is carried out for base shear and plate stresses.**

IndexTerms - **Elevated water tanks, sloshing effect, STAAD.Pro, base shear, plate stresses.**

I. INTRODUCTION

Water tanks are the structures used for storing liquids for various purposes like farming, drinking water, irrigation, etc. Overhead water tanks can be classified as

i) Rectangular overhead water tanks.
ii) Circular overhead water tanks.
iii) Intze type tanks.

For smaller capacities, say 50,000 liters to 75,000 liters, rectangular tanks are used. They become uneconomical for large capacities. Circular overhead water tanks can store water up to 7, 50,000 liters. Their diameter varies from 5-15m and height 3-4.5m. Whereas Intze type of tank is used to store massivevolume of water. These are now oftentimes used in cities with a potential of 1 million liters. All overhead water tanks require roof on the pinnacle and staging at bottom to assist them (Bhavikatti 2008).

Natural disasters mostly earthquake can cause severe harm to the water storing reservoirs. These reservoirs are often used in various seismic zones. Thus their seismic behavior becomes an vital factor.The violent behavior of fluid inside a container/tank with free surface is recognised as sloshing. The presence of a free surface in partially crammed liquid containers permits for a fluid motion relative to the containers, this is referred as 'liquid sloshing'. If the liquid is allowed to slosh freely it can generate forces that cause extrahydrodynamic stress in case of storage tank and extra vehicle acceleration in case of moving tanks and space automobiles (Choudhary and Bhora 2017).

II. LITERATURE REVIEW

Numerous researchers have published work on rectangular tanks and circular tanks. Few researchers published work on analysis of elevated tank under dynamic loading are reviewed in this section.

A simplified dynamic analysis for the response of elevated water tanks which are subjected to seismic forces was first given through George W. Housner (1957, 1963). According to creator the analysis of such tanks have to take into account the motion of Study of water relative to tank and additionally the movement of tank relative to the ground. If the tank is totally crammed with water or is empty, then it will behave as a one-mass structure. But if the tank has a free surface, as in many cases, there will be sloshing of water in the course of earthquake, and at this stage the tank will be indisputably a two-mass structure.

For inflexible tanks containing two beverages under horizontal excitation with an arbitrary temporal variant Tang (1992) introduced an specific solution. Both analytical and FEM techniques have been employed in analysis. The response features examined protected the hydrodynamic pressure, base shear and base moments. It was once proven that for tank containing two liquids, sloshing frequencies and wave heights are features of liquid densities whereas in case of tank with one liquid it is not.

Seismic response of regular cylindrical tank was once analyzed through Kilic (2009). Arbitrary Lagrangian Eulerian (ALE) approach was used and investigated to stimulate the sloshing effect with the aid of fluid-structure coupling. Also contrast was once made with the API 650 approach. In first phase of learn about sloshing wave height was examined for cylindrical tank subjected to East-West and the North-South factors of the YPT ground motionrecords. In the 2d part, the cylindrical tank used to be subjected to all three components of the YPT records.

Linear potential theory in conjunction with conformal mapping technique to develop rigorous mathematical models for two-dimensional transient sloshing in non deformable baffled horizontal circular cylindrical vessels, full of incompressible fluids to impulsive depth, and subjected to impulsive time dependent lateral accelerations was used by Hasheminejad et al (2014). Effects of various parameters such as necessary period, peak to diameter ratio, seismic layout class and tank size on seismic response elements of elevated water tank used to be evaluated with the aid of Kianoush et al. (2015). Total forty eight prototypes had been selected and had been designed primarily based on contemporary codes and standards. Furthermore cracking propagation sample was additionally studied.

III. METHODOLOGY

Three tanks of capacity 50, 70 and 90 m^3 are analyzed using IS: 1893 (Part-2) 2014 and hydrodynamic forces are calculated, which are applied during seismic analysis of tank in software. Tanks are analyzed for increasing water column from one fourth fill to full fill conditions. FEM software STAAD.Pro is used for analysis, maximum plate stresses and base shear obtained for hydrostatic and hydrostatic sloshing case are compared.

IV. STRUCTURAL MODEL OF TANK

A RCC elevated circular water tank of $50m^3$ capacity is modelled using STAAD.Pro.Tank details are given below,

Internal diameter- 5m
Height -3m (Including FB-0.4m)
Wall thickness - 0.2m
Height of staging-12
Tank is located in seismic zone IV.
Soil condition- hard soil
Grade of concrete is M30.

Tank is primarily modeled with proper units for given dimensions. Various elements of the tank are readily available from structure wizard option in software. After finalizing the model, material properties, support conditions and loadings are assigned to the structure and the structure is analyzed.

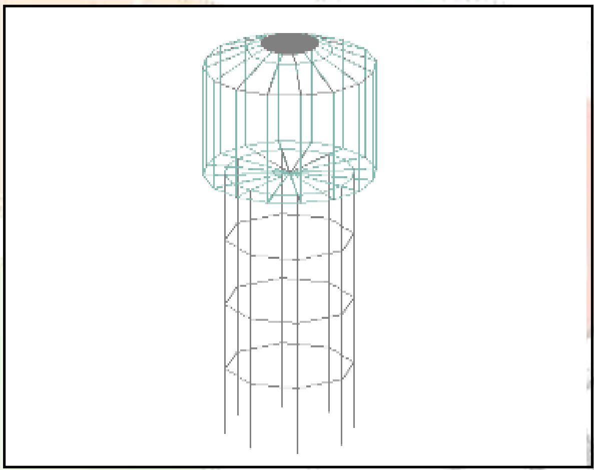

Figure 1 Preliminary model of tank in STAAD.Pro

Analysis steps are discussed in detail below,

i. Material properties**:** In the define option we can define the material properties for column, and beam. Plate thickness is also assigned. We can assign concrete, steel, aluminum sections for these sections. For this model we have used concrete material for all the elements.

Table 1 Material properties of tank model

Density (kg/m3)	2400
Poisson‟s ratio	0.17
Modulus of elasticity (N/m2)	2.17 x109

ii. Supports**:** Fixed support is provided at the bottom of staging

iii. Loading: Loads applied are dead load live load. From the *loads and definition* menu loads can be assigned to the structure. Live load is assigned in form of hydrostatic and hydrodynamic pressure on tank walls.

iv. Analysis**:** Tank is analyzed for given support and loading conditions. After analysis results can be obtained for various given loads combinations. Nodal displacements, beams stresses, plate stresses, and plate contour and also shear force and bending moments of required sections are achieved after analysis.

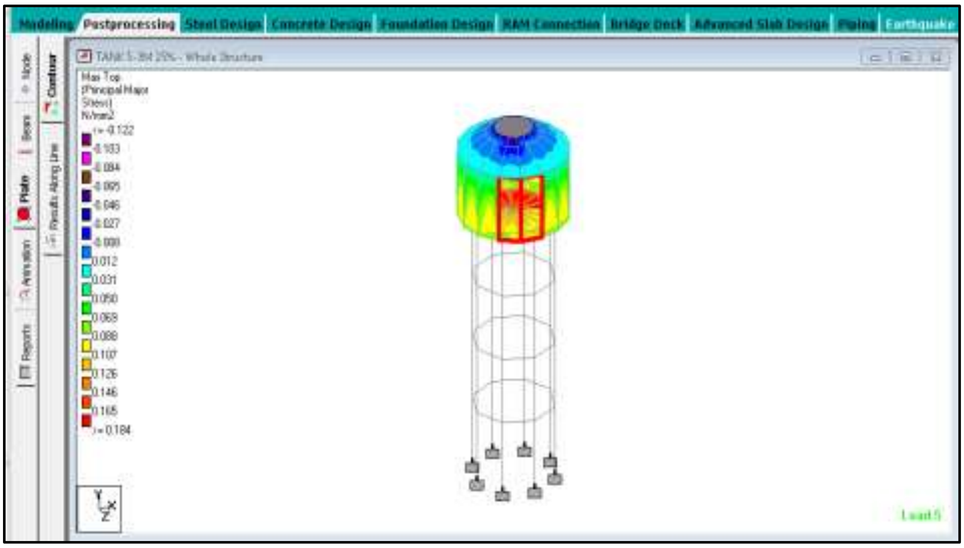

Figure 2 Maximum Plate Stresses on tank walls

V. RESULTS AND DISCUSSIONS

Analysis results of tanks are presented in the form of graphical representation. Results are based on the comparison of plate stresses and base shear of these models due to hydrostatic effect and hydrostatic plus sloshing effect.

a) Plate stresses v/s Water column

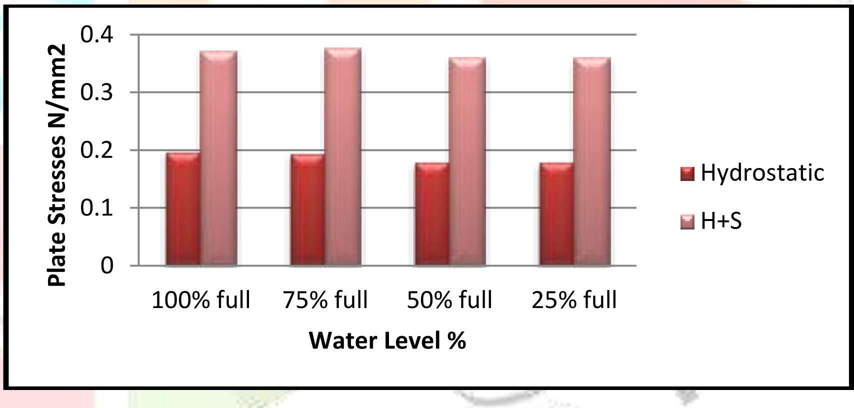

Figure 3 Plate stresses v/s water column for $50m^3$ capacity of tank

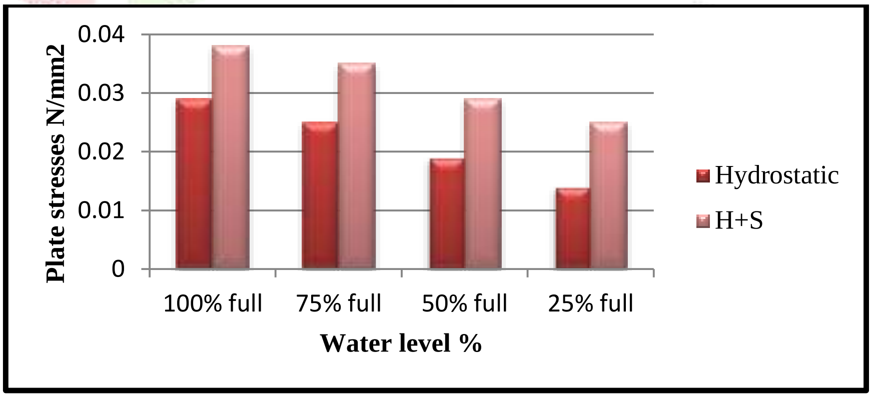

Figure 4 Plate stresses v/s water column for $70m^3$ capacity of tank

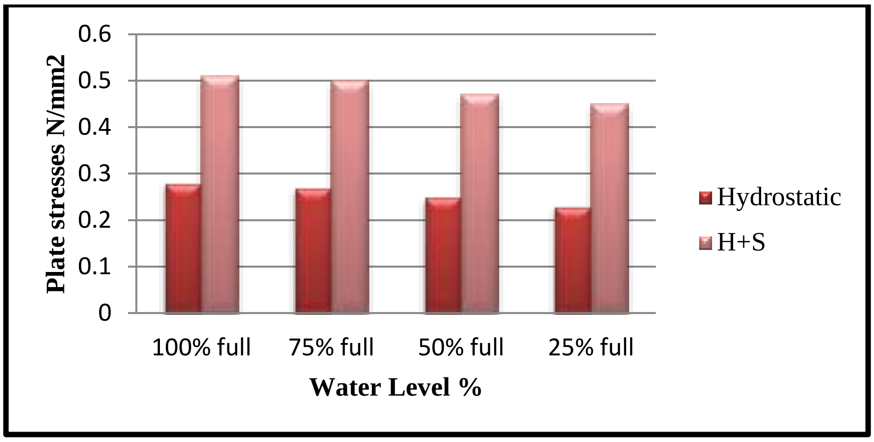

Figure 5 Plate stresses v/s water column for 90m^3 capacity of tank

For 50m^3 capacity tank, maximum plate stresses are analyzed for 100 to 25% full water column conditions. For 100% full water column condition plate stresses for hydrostatic condition is 0.198 N/mm^2 and for hydrostatic sloshing condition is 0.37 N/mm^2. Similarly for 75% full water column, stresses increases from 0.195 N/mm^2 (H) to 0.376 N/mm^2 (H+S). In case of 50% and 25% full condition, stresses increase is same for both conditions i.e. from 0.18 N/mm^2(H) to 0.36 N/mm^2(H+S).

Now for 70m^3 capacity tank, plate stresses for 100% full water column condition in case of hydrostatic condition is 0.26 N/mm^2 and for sloshing is 0.45 N/mm^2. Nowfor 75% condition stresses increases from 0.24 N/mm^2 to 0.44 N/mm$^{2.}$ In case of 50% and 25%full condition stresses increase from 0.22 N/mm^2 to 0.41 N/mm^2 and 0.20 N/mm^2 m to 0.38 N/mm^2 respectively.

For 90m^3 capacity tank, plate stresses for 100% full water column condition in case of hydrostatic condition is 0.28 N/mm^2 and for sloshing is 0.51 N/mm^2. Now for 75% condition stresses increases from 0.27 N/mm^2 to 0.5 N/mm^2. In case of 50% and 25% full condition stresses increase from 0.25 N/mm^2 to 0.47 N/mm^2 and 0.23 N/mm^2 m to 0.45 N/mm^2 respectively.

b) Base Shear v/s Water column

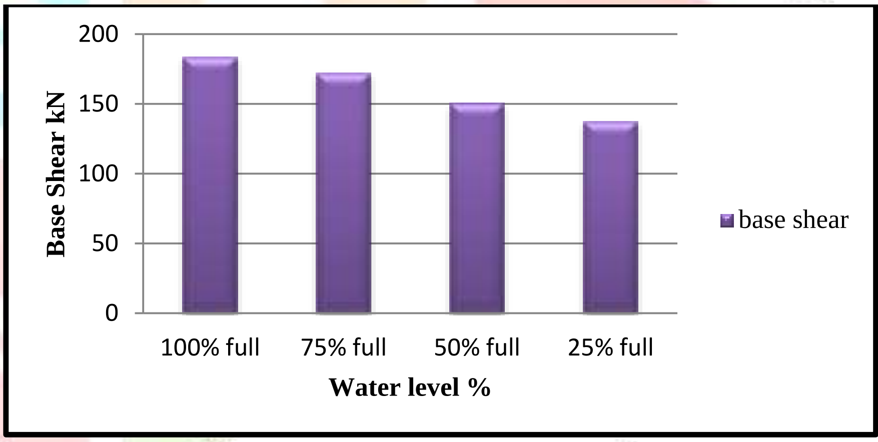

Figure 6 Base shear v/s water columns for 50m^3 capacity of tank

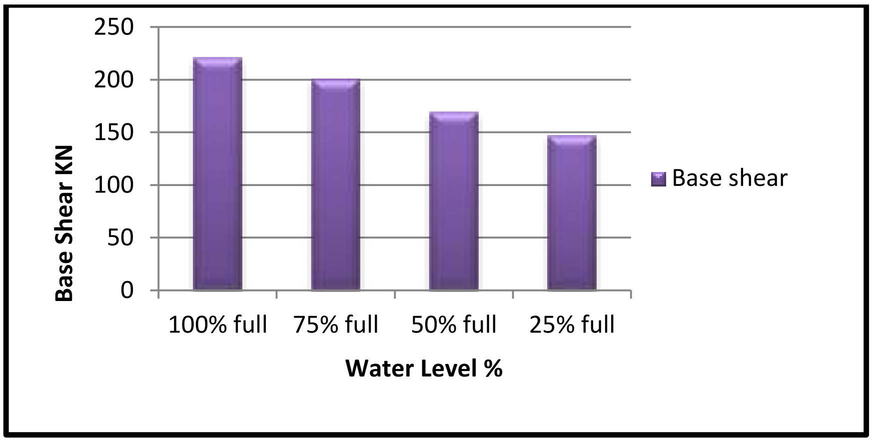

Figure 7 Base shear v/s water columns for 70m^3 capacity of tank

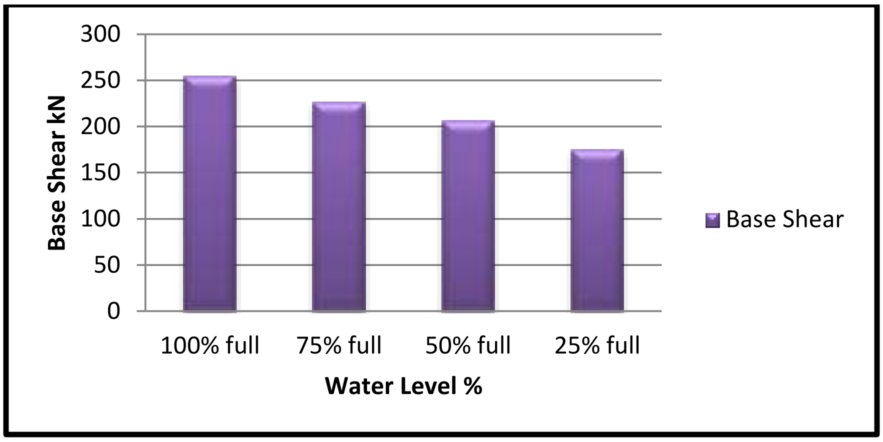

Figure 8 Base shear v/s water columns for 90m^3 capacity of tank

For 50m^3 capacity tank, maximum base shear is analyzed for 100 to 25% full water column conditions. For 100% full water column condition value of base shear is183.25 KN. Similarly for 75% full water column, base shear is 171.75 KN. In case of 50% and 25% full condition base shear values are 150.33 KN and 136.89 KN respectively.

For 70m^3 capacity tank, maximum base shear is analyzed for 100% full to 25% full water column conditions. For 100% full water column condition base shear value is 220.49 KN. Similarly for 75% full water column, base shear is 200.07 KN. In case of 50% and 25% full condition base shear values are 168.64 KN and 146.52 KN respectively.

For 90m^3 capacity tank, maximum base shear is analyzed for 100% full to 25% full water column conditions. For 100% full water column condition base shear value is 254.4 KN. Similarly for 75% full water column, base shear is 225.97 KN. In case of 50% and 25% full condition base shear values are 205.96 KN and 174.54 KN respectively.

VI. CONCLUSIONS

On the basis of results obtained from analysis we can conclude that,

- Plate stresses increase with increase in water column.
- Stresses increase from 20 to 45 percent for 50 to 90 m^3 capacity tank.
- Plate stresses are more for sloshing loads compared to only hydrostatic loads.
- About 43 to 48 % increment in stresses is observed for sloshing effect.
- Base shear value increases for increasing water level in tanks by 5 to 15 percent.

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